3rd Workshop on Microwave Cavities and Detectors for Axion Research

Tuesday 21 August 2018 - Friday 24 August 2018

Lawrence Livermore National Laboratory

Book of Abstracts

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ABRACADABRA Experiment

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ADMX 2A Cavity Array Mechanical Design

Author: Joe Gleason[1]

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The next generation (2A) ADMX detector will achieve a tuning range of 1.4 - 2.1 GHz with an array of 4 frequency-locked cavities. A final design of the ADMX 2A 4 cavity array has been prepared. We will present the mechanical aspects of the 4 cavity array design and how it will integrate with the existing ADMX insert.

Summary:

We will present the mechanical aspects of the ADMX 2A 4 cavity array design and how it will integrate with the existing ADMX insert.

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ADMX HiRes Analysis

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ADMX HiRes Analysis

Author: Shriram Sadashivajois[None]

Co-authors: David Tanner [1] ; Leanne Duffy [2] ; Neil Sullivan Sullivan [1]

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This is a report on the progress on the HiRes data analysis project. The time series data is read using a c++ code. An attempt is made to enhance the signal by using window functions and adding zeros to the time series. The data is then fourier transformed to look for the blind injection signal.

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ADMX Sidecar Results

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Ansys HFSS Tutorial

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This informal session will provide an introductory tutorial on the use of Ansys High Frequency Structure Simulator (HFSS) with a live demonstration of an example cavity model. Specific features relevant to achieving accurate simulation results will be highlighted.

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Axion Detection with Precision Frequency Metrology

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We propose a new approach to axion detection based on precision frequency measurements as opposed to the traditional power detection techniques[arXiv:1806.07141]. The approach utilises a high Quality Factor cavity supporting two mutually orthogonal modes. We demonstrate how axion modified Maxwell equations lead to either a beam splitter or parametric interaction terms in the axion up- or downconversion cases respectively. The term couples two modes of different frequencies with the axion frequency (mass) being either the difference (upconversion) or sum (downconversion) of the frequencies of the modes. The derivation introduces a unitless two-mode geometric coefficient characterising the coupling between two particular modes. The Hamiltonian term in the rotating wave approximation is proportional to axion complex amplitude and the axion-photon coupling constant.

The double mode cavity could be used for the traditional power detection when one or both modes are strongly pumped. Although such a method would be inefficient compared to the common DC magnet technique. On the other hand a possibility to employ a highly sensitive cross correlation technique may lead to comparable results. Instead of measuring tiny amounts of power deposited in the cavity modes, we propose to measure frequency shifts associated with the axion coupling terms. Based on the equation of motion of axion coupling modes, we calculate frequencies shifts of the modes that can be observed with one of a few frequency control techniques. We predict both real and imaginary parts of the resonance frequency to be sensitive to axions depending on the type of coupling. We also calculate transfer functions from axion induced couplings to phase noise of two orthogonally polarised modes in both open loop and closed loop regimes. Based on these transfer functions, we are able to estimate axion sensitivity of the dual mode axion detection approach. Even a room temperature microwave oscillator realisation of the proposed techniques will result in new limits on the coupling between axions and photons. The cryogenic realisation, if implemented, could exclude axion-photon couplings below the predicted DFSZ coupling. The power of the new approach relies on the fact that unlike in the power detection method where the sensitivity is limited by the

thermal (or quantum) noise in the readout, the frequency sensing is limited by resonator linewidths and their internal fluctuations. For modern cryogenic microwave resonators, Quality factors exceed 10^9 giving fractional frequency stability better than 10^{-16} have been demonstrated. Such levels of frequency stability provide better signal-to-noise ratio that the best power detection techniques. The main advantages of the proposed frequency control
method are: 1. magnet-free. Unlike traditional haloscopes, the proposed method does not require a strong DC magnetic fields; 2. SQUID-free. All sensitivities calculated in this work are based on usage of traditional low noise semiconductor amplifiers. Though superconducting technology might be used in the future, its presence is not crucial contrary to traditional methods; 3. cavity volume independence. Although cavity volume influences many parameters of the experiment such as resonance frequencies and quality factors, the sensitivity is not directly proportional to this parameter unlike in traditional haloscopes. This removes the major obstacle for higher mass ($f_a > 10$GHz) axion searches. Moreover, optical cavities might be used to probe otherwise unaccessible regions of THz and infrared spectrum as well as millimiter-wave and microwave frequencies; 4. Liquid-Helium temperature operation (> 4K) where only a limited number of components such as cavity and amplifiers have to be at low temperature. This factor removes the need of dilution refrigeration that is a key component in traditional haloscopes making the whole experiment available to a broader audience. Although dilution refrigeration might give some incremental improvement in the axion search, all ultra-stable microwave and optical clocks and oscillators do not require temperatures below 4K. 5. access to higher and lower frequency ranges. The fact that actual axion mass is either the sum or difference of working frequencies opens a possibility to search for axions in less accessible frequency rages. For instance, working around 20GHz, one is able to probes axion masses in the vicinity of 40GHz, where experiments are significantly more difficult; 6. limited power levels. Although, the sensitivity does explicitly depend on power levels, on the current calculation only limited power levels are used unlike in some other proposals; 7. axion phase sensitive. Comparing to DC magnet haloscopes, the dual frequency method is able to provide additional information about axions, particularly its phase relative to pump signals, although that might lead to more complicated detection schemes; 8. KSVZ/DSFZ achievable. It is estimated that the cryogenic dual mode experiment is able to achieve the limit of the widely accepted axion dark matter models. On the other hand, even a tabletop search may lead to competitive limits on dark matter; 9. broadband search for low mass axions is possible. It is demonstrated that a wideband search that does not require tuning is possible.

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Axion dark matter search at CAPP

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The axion is a consequence of the PQ mechanism to solve the strong-CP problem and has been considered as an attractive candidate for cold dark matter. The Center for Axion and Precision Physics Research (CAPP) of the Institute for Basic Science (IBS) in South Korea has completed the construction of the infrastructure for axion dark matter search experiments. Multiple experiments are currently under preparation for parallel operation targeting at different mass ranges. The ultimate goal of our center is to be sensitive to the QCD axion models over a wide range of axion mass. The current approaches to achieve this goal are three folds – commissioning high field magnets, designing high frequency cavities, and developing low noise amplifiers. We present the status of the experiments and discuss the future prospects.

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CAPP-PACE experiment with a target mass range around 10 μeV

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CAPP-PACE is a pilot experiment of IBS/CAPP for direct detection of axions with a mass around 10 μeV based on Sikivie's microwave cavity scheme. The detector is equipped with an 8 T superconducting magnet and employs a dilution refrigerator that lowers the physical temperature of a high Q-factor split-type cavity to less than 45 mK. The frequency tuning system utilizes piezoelectric actuators with interchangeable sapphire and copper rods. The feeble signal (˜10-24 W) from the cavity is amplified and transmitted through the RF receiver chain with a HEMT amplifier whose noise temperature is around 1K. I will present the results of CAPP's first physics data runs in the axion mass range from 2.45 to 2.75 GHz and discuss our future plans and R&D projects.

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Capacitor Cavities for Axion Searches

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Dark Matter Radio

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The Dark Matter Radio (DM Radio) is a sensitive search for sub-eV axion and hidden photon dark matter covering the peV to μeV mass range. DM Radio uses a superconducting, tunable lumped-element LC resonator with SQUID-based readout. The DM Radio Pilot, a small-scale demonstrator, is now in operation. Planning and construction of a larger Phase I detector, which will set important new limits on axion and hidden photon dark matter, is underway. In this talk, I will discuss the motivation, detection strategy, status and prospects for the DM Radio experiment and show the dark matter phase space that DM Radio will search over the next several years.

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Demonstration of Scan Rate Enhancement in a Mock-Haloscope Experiment using Quantum Squeezing

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Haloscopes looking for dark matter axions have their scan rates limited by noise that is quantum in origin: that is, it originates from the uncertainty principle enforcing itself upon the measurement of non-commuting observables. This noise can be circumvented by preparing the haloscope's cavity not in its ground state, but in a squeezed state of the microwave field, wherein one of the quadratures of the cavity has its variance reduced below the level of vacuum fluctuations. Subsequent to the displacement of the cavity state by a highly occupied but weakly coupled axion field, the squeezed quadrature can be measured with precision far greater than what would be permitted in the absence of squeezing. We present a squeezed state receiver setup, which features a cavity surrounded by a pair of flux-pumped Josephson parametric amplifiers used to create and read-out the squeezed state. Under conditions meant to mimic some of the salient features of an axion haloscope, we demonstrate the the utility of quantum squeezing towards the detection of a weak microwave tone that we inject into the cavity. Using squeezing, we achieve a factor of 2.3 improvement in the effective scan rate of our mock-haloscope over the unsqueezed case.

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Dielectric tuning of cavities

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Haloscope-based axion searches are typically planned around a single, costly superconducting magnet. As a corollary to this design constraint, the number of cavities that can be fit into a fixed magnet bore will increase as the targeted axion mass increases, i.e. as the haloscope cavity radius decreases. Mechanically tuning an array of N cavities, where N is large, introduces a suite of physics and engineering challenges collectively referred to as "the Swiss watch problem". Non-mechanical tuning strategies would relieve some constraints on the mechanical tolerance requirements of cavity dimension and tuning rod precision, as well as reducing the heat load from simultaneous actuation of many tuning motors. We have demonstrated cavity tuning on the order of a linewidth by loading a 4-GHz cavity with a strontium titanate (STO) crystal – a ferroelectric material. The permittivity of this material varies under the application of an external DC voltage. Changing the dielectric strength of a small fraction of the cavity volume allows the cavity frequency to be tuned non-mechanically. We present a first demonstration of this tuning strategy, as well as recommendations for future work based on our results.

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Haloscope at Yale Sensitive to Axion CDM (HAYSTAC) Phase I Results and Phase II Upgrades

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We report on the results from a search for dark matter axions with the HAYSTAC experiment using a microwave cavity detector at frequencies between 5.6-5.8 GHz. We exclude axion models with photon couplings a factor of 2.7 above the benchmark KSVZ model over the mass range 23.15<m_a<24.0

μeV. We achieve a near-quantum-limited sensitivity by operating at a temperature T < hv/2kB and incorporating a Josephson parametric amplifier (JPA), with improvements in the cooling of the cavity further reducing the experiment's system noise temperature to only twice the Standard Quantum Limit at its operational frequency, an order of magnitude better than any other dark matter microwave cavity experiment to date. This result concludes the first phase of the HAYSTAC program. The second phase of the HAYSTAC program will incorporate an updated dilution refrigerator with 3X the cooling power at base temperature, updated cryogenics that improve the quality factor of the cavity by 40%, and a squeezed-vacuum state receiver that promises a 2.3X scan rate enhancement by evading the standard quantum limit for thermal noise.

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High-Q 3D Photonic Bandgap Cavities for Axion Detection

Author: Ankur Agrawal[None]

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Axion dark matter haloscope requires high magnetic field to convert dark matter into microwave photons and high-Q cavities to store these photons for measurement. Copper cavities with Q ˜ 10^4 must be used since the high magnetic field makes it challenging to utilize superconducting cavities. Photonic Bandgap (PBG) cavities made out of high contrast, low-loss dielectric material can operate in high field and achieve a Q-values of 10^8. I will discuss the design and simulation results of a 3D FCC-type lattice constructed using alternating layers of Rutile and Sapphire which shows a large bandgap of ˜ 31% centered around the desired cavity frequency.

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Introduction & Welcome

Author: Gianpaolo Carosi[1]

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In this talk I will discuss the motivation behind this workshop by introducing the dark matter axion and the haloscope technique to search for it. This technique uses microwave cavities to resonantly enhance the conversion rate of axions to potentially detectable levels. I will layout the number of design challenges facing experimental efforts moving forward.

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Introduction to RF-Structures and Their Design

Author: Frank Krawczyk[1]

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The numerical design chapter of the class addresses two topics: (1) Numerical Methods that include resonator design basics, introduction to Finite Difference, Finite Element and other methods, and (2) Introduction to Simulation Software that covers 2D and 3D software tools and their applicability, concepts for problem descriptions, interaction with particles, couplers, mechanical and thermal design, and finally a list of tips, tricks and challenges.

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Introduction to RF-structures and their design

Author: Frank Krawczyk[1]

[1] *Los Alamos National Laboratory*

The numerical design presentation addresses two topics: (1) Numerical Methods that include resonator design basics, introduction to Finite Difference, Finite Element and other methods, and (2) Introduction to Simulation Software that covers 2D and 3D software tools and their applicability, concepts for problem descriptions, interaction with particles, couplers, mechanical and thermal design, and finally a list of tips, tricks and challenges.

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MADMAX: Introduction and status

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Dark matter axions or axion-like particles produced after inflation can have mass of 40—400 μeV. Under a magnetic field, the axions could induce electromagnetic waves of 10—100 GHz. Such a signal could be enhanced by an array of dielectric disks. The experiment, MADMAX, aims to detect these post-inflationary QCD axions. The basic concept, current status, and recent activities of the experiment will be presented.

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Magnetic shielding and source-mass characterization in the ARIADNE axion experiment

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The Axion Resonant InterAction Detection Experiment (ARIADNE) collaboration will search for the QCD axion using a Nuclear Magnetic Resonance based technique where the axion acts as a mediator of spin-dependent forces between an unpolarized Tungsten source mass and a sample of polarized helium-3 gas. The experiment relies on limiting ordinary magnetic noise with superconducting magnetic shielding as well as a stable rotary system to modulate the axion-signal from the source mass. Updates on thin-film superconducting shielding, rotating source mass characterization, and progress on the experiment will be discussed.

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Modified Axion Electrodynamics and the BEAST Experiment

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Co-authors: Ben McAllister [2] ; Maxim Goryachev [3]

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First I take a new look at modified axion electrodynamics as modifying the magnetization and polarization of the vacuum, which was first discussed in [1]. The main result shows both magnetic and electric sensing techniques may be implemented for low-mass experiments where the Compton wavelength is much greater than the size of the experiment. Following this we propose and present first results of a broadband low-mass axion detection experiment, which uses electric sensors in a conventional solenoidal magnet aligned in the laboratory z-axis (as implemented in standard haloscope experiments). We show that a capacative sensors or electric dipole antennas coupled to a low noise amplifier can be implemented as a sensitive detector. We call this technique Broadband Electric Axion Sensing Technique (BEAST). We present the theoretical foundation for this experiment along with the first experimental results. Preliminary results constrain $g_{a\gamma\gamma} >\sim 2.35 \times 10^{-12}$ GeV^{-1} in the mass range of 2.08×10^{-11} to 2.2×10^{-11} eV, and demonstrate potential sensitivity to axion-like dark matter with masses in the range of 10^{-12} to 10^{-8} eV

[1] F. Wilczek, Physical Review Letters 58, 1799 (1987)

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Multiple-cell cavity for high mass axion dark matter search

Author: Junu Jeong[1]

Co-author: SungWoo YOUN [2]

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Haloscope axion dark matter search experiments typically consider arrays of multiple cavities to increase the detection volume in exploring high mass regions. We, IBS/CAPP at KAIST, introduce a new concept, dubbed pizza-cylinder cavity, which is superior to conventional multiple-cavity design in terms of detection volume, simplicity of the experimental setup, and facilitation of the phase-matching mechanism. This idea is promising for detecting high frequency axion dark matter with enhanced experimental sensitivities. We present the characteristics of this design and demonstrate the experimental feasibility using a double-cell cavity.

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Open Discussion

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Operation of a ferrimagnetic Axion haloscope at ma = 58 microeV

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In the QUAX experiment, dark matter axions are searched by means of their resonant interactions with electronic spins in a magnetized sample. In principle axion-induced magnetization changes can be detected embedding a sample in a rf cavity under a static magnetic field. In this presentation we describe the operation of a prototype ferrimagnetic haloscope, whose sensitivity is limited only by thermal effects. With a preliminary axion search, we are able to produce an upper limit on cosmological DSFZ axions of gaee < 4.9 × 10ˆ-10 at 90% C.L. for an axion mass of 58 microeV (i.e. 14 GHz) and assuming a local DM density of 0.45 GeV/cmˆ3. This is the first reported measurement of the coupling between cosmological axions and electronic spins. Some preliminary measurements with a NbTi superconducting cavity will be presented.

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Optically Pumped Magnetometers

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Optically pumped magnetometer for a low frequency axion detector

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The most sensitive cryogen-free magnetic-field sensor is an optically pumped magnetometer. At LANL, we will investigate its use in an LC-circuit style axion search around 300 kHz, operating at room temperature. The tunability of the OPM means that only one magnetometer is required to search a significant range of low frequencies, between ˜1 kHz and 1 MHz, with an existing OPM.

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Orpheus: Extending the ADMX QCD Dark-Matter Axion Search to Higher Masses

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Axions in our local dark matter halo could be detected using an apparatus consisting of a resonant microwave cavity threaded by a strong magnetic field. The ADMX experiment has recently used this technique to search for axions in the few $\mu eV/c^2$ mass range. However, the ADMX search technique becomes increasingly challenging with increasing axion mass. This is because higher masses require smaller-diameter cavities, and a smaller cavity volume reduces the signal strength. Thus, there is interest in developing more sophisticated resonators to overcome this problem. We present the progress of the ADMX Orpheus prototype experiment. This uses a dielectric-loaded Fabry-Perot resonator to search for axion-like particles between at axion masses approaching 100 $\mu eV/c^2$.

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Photonic Bandgap Techniques

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Photonic Geometries for Light Trapping and Manipulation

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Co-author: Steven Johnson [2]

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In the first half of the talk, I will do a quick survey of photonic crystals with a particular emphasis on their structural designs, bandgap properties, defect modes and cavity characteristics. In the second half, I will discuss more recent results which involve large-scale computational optimization of photonic cavities for nonlinear optical applications, especially computational design of photonic cavities with more sophisticated functionalities such as exactly tailored widely-separated multiple resonances and maximal overlap between cavity modes.

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Quantum Oscillators and Bayesian Searches

Author: George Chapline[1]

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There is currently an LDRD project to develop the idea of using an analog quantum oscillator array to find the optimum search strategy for Bayesian search and control problems. Such an array could also be used to detect signals which are below the level of a single quantum excitation.

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Quantum Sensors and the Fundamental Limits of Electromagnetic Axion and Hidden-Photon Search

Author: Kent Irwin[1]

Co-authors: Arran Phipps [2] ; Betty Young [3] ; Carl Dawson [2] ; Cyndia Yu [2] ; Dale Li [4] ; Hsiao-Mei Cho [4] ; Jeremy Mardon [5] ; Peter Graham [2] ; Saptarshi Chaudhuri [6] ; Stephen Kuenstner [2]

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We describe the fundamental limits on the scan sensitivity of axion and hidden-photon dark matter searches probing the electromagnetic coupling in a single mode with a phase-insensitive amplifier. An optimized search with a quantum-limited amplifier provides substantial sensitivity benefit, in particular at low masses/frequencies, where optimization provides a substantial enhancement due to sensitivity outside of the detector bandwidth. The figure of merit for wideband dark matter searches is the integrated sensitivity of the receiver circuit, and the integrated sensitivity is constrained by the Bode-Fano criterion. We demonstrate that the optimized single-pole resonator read out by a quantum-limited amplifier is close to the Bode-Fano limit, establishing such a search technique as a fundamentally near-ideal setup for dark matter measurement with a single electromagnetic mode. These results strongly motivate the use of quantum measurement techniques in dark-matter searches (e.g. squeezing, photon counting, and backaction evasion), which evade these limits. We describe in particular the use of quantum measurement techniques in the radio-frequency frequency range (below ˜300 MHz) where the resonator is not in the ground state in practical experiments (kT>hf), and describe the Zappe Photon Upconverter (ZPU), which can be used to implement techniques including backaction evasion to outperform the Standard Quantum Limit at RF frequencies.

1

Quantum measurement at microwave frequencies with superconducting circuits

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Recent progress in the fabrication and control of quantum coherent superconducting circuits has enabled new experiments that probe the fundamental physics of quantum measurement. I will describe our recent experiments that harness near quantum limited parametric amplifiers and superconducting qubits to study physics ranging from examining quantum trajectories associated with

spontaneous emission to extending thermodynamics into the quantum regime in a experimental realization of a quantum Maxwell's demon.

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R&D Beyond 10 GHz

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Reaching the 5–9 μeV Range with ADMX: Multi-Cavity Array

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Co-authors: David Tanner [2] ; Neil Sullivan [2] ; joseph gleason [3]

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The aim of the Axion Dark Matter eXperiment (ADMX) is to detect CDM axions in the halo of our Galaxy. ADMX seeks to detect axions by observing the conversion of axions to microwave photons in a high-Q resonant cavity in a strong magnetic field (an Axion haloscope). ADMX recently has completed successfully a search over the 2.66–2.81 μeV mass range with unprecedented sensitivity. For higher mass range searches, ADMX has developed multi-cavity arrays as the heart of a haloscope for axion masses in the 5–9 μeV range. We will present design aspects and preliminary study results of a 4-cavity array prototype.

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Recent Results with ADMX Experiment

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Recent Results with the ADMX Experiment

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The ADMX experiment is an axion haloscope using a microwave cavity in a strong magnetic field to search for dark matter axions. I will present on results from our run 1A in which we excluded the range of axion-photon couplings predicted by QCD axions for axion masses between 2.66 and 2.81ueV. These results marked the first time a haloscope experiment achieved sensitivity to the well motivated DFSZ axion. In addition, I will provide updates on the status of the current run in are searching for axions in the 2.82-3.31ueV mass range.

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Reducing Dark Counts and Backgrounds in Qubit Based Photon Detectors

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Co-authors: Aaron Chou [2] ; Ankur Agrawal ; David Schuster [3]

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Two challenges in building useful single photon detectors are the detector dark rate and spurious background photons. Since the detector is agnostic to the source of the photons, background photons are indistinguishable from photons occupying the cavity from a axion-photon interaction. I will describe the aggressive line filtering used to reduce background photon probabilities to 1e-5 (@˜10GHz). Dark counts of the detector are a result of spurious occupation a qubit used to perform the quantum non-demolition measurement (QND) of the photon. The probability of having a qubit dark count are a few percent (1-5%) and can vary from sample to sample. One possible technique to mitigate the errors resulting from qubit occupation is to actively cool the qubit before the detection protocol. Another option is to employ multiple QND detectors each independently measuring the same photon. With 4 detectors this may allow us to achieve dark count probabilities of 1e-8. I will describe the status and design of the experiment under construction to test joint measurement of a single photon.

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Sidecars Future and Other Cavity Concepts

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The Sidecar experiment is a path finder experiment for higher frequency iterations of the ADMX experiment and is capable of producing competitive science results. The next generation of the Sidecar will feature a new form factor and be used to test design changes and new hardware. Cavity concepts for a third generation of the Sidecar experiment will also be discussed.

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Superconducting Cavity R&D at Fermilab

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Superconducting Thin Films For Levitation of NIF Targets

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A key challenge in achieving ignition at NIF is the asymmetries introduced by capsule supports, which perturbs the implosion and reduces yield. This talk will detail a new approach to develop stable, support free levitation using thin superconducting films of magnesium diboride, deposited on the surface of the diamond capsules. We have demonstrated straightforward, scalable formation of MgB2 thin films down to 50 nm using a two-step vapor reaction technique. The films have critical temperatures up to 34 K, and surface roughnesses as low as 1 nm, making them promising candidates for quantum levitation.

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The 3 cavity prototypes of RADES, an axion detector experiment using microwave filters

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The Relic Axion Detector Experimental Setup (RADES) is an axion search project that uses a microwave filter as a detector. This type of filters may allow the search for dark matter axions of masses in the decade 10-100 μeV. This presentation will focus on the analytical model, simulations, design and construction of the 3 different cavity prototypes of RADES. The results of the first tests of one of the prototypes are also going to be presented. The filters consist of 5 stainless steel sub-cavities joined by rectangular irises. The size of the sub-cavities determines the working frequency, the amount of sub-cavities determine the working volume. A theoretical model was built in order to describe the detection properties of the cavities. Simulations were done to establish the optimal design of the microwave filters. The first cavity prototype was built in 2017 to work at a frequency of $\sim$ 8.4 GHz and it was placed at the 9 T CAST dipole magnet at CERN. Two more prototypes were designed and built in 2018. The aim of the new designs is to find and test the best cavity geometry in order to scale up in volume and introduce an effective tuning mechanism. A description of the theoretical framework, the simulations, the construction, and some preliminary results of the electromagnetic properties of the first cavity prototype are going to be presented. The results show the potential of this type of filter to reach QCD axion sensitivity at X-Band frequencies.

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The Microstrip SQUID Amplifier in ADMX

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A critical enabling technology for ADMX is the low-noise microwave amplifier. The amplifiers used in ADMX are about 10 times lower noise than the best available commercial amplifiers, enabling ADMX to cover ground in months that would otherwise take decades. One kind of amplifier used in ADMX is the Microstrip SQUID Amplifier (MSA). The MSA was inspired by the unique challenges of ADMX, with the first working MSA demonstrated in 1998, and an MSA powering the first DFSZ-sensitive Axion search results published in 2018. I will present an overview of the MSA, including a review of the basic operating principles, design principles, challenges presented by the ADMX project, practical implementation, and performance of devices used in operation in ADMX.

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The ORGAN Experiment

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We discuss the current status of the ORGAN experiment, a high mass axion haloscope. The goal of ORGAN is to search the promising high axion mass regime, covering the range of masses proposed by the SMASH model, amongst other theoretical predictions. This talk will include a review of progress and results to date, then cover developments in cavity design and R&D, and the next science run of the primary haloscope experiment. Cavity R&D builds on our work on tunable super-mode dielectric resonators [1], with applications to the high-mass regime. These resonators can be designed to have scan rates improved by 1 to 2 orders of magnitude compared with simpler haloscope designs.

The plans for the next experiment, which will operate in a new dedicated dilution refrigerator with a base temperature of 7 mK and a 14 T superconducting solenoid, will be discussed. We will also give an overview of some complementary experiments that are under development at UWA to operate alongside ORGAN, including wide mass range searches for axion-like particles.

1. Ben T. McAllister, Graeme Flower, Lucas E. Tobar, Michael E. Tobar, "Tunable Super-Mode Dielectric Resonators for Axion Haloscopes", Phys. Rev. Applied 9, 014028 (2018)

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Ultra High Field Solenoids and Axion Detection

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The National High Magnetic Field Laboratory in Tallahassee Florida designs, builds, and operates the world's most powerful magnets; up to 45 T dc and 100 T for ˜10 ms pulses. While most magnets are used for condensed-matter physics and have small bores (3 – 5 cm), large bore magnets have been built and operated such as 11.4 T in a 60 cm bore or 13 T in a 50 cm bore.
High Temperature Superconductors (HTS) were discovered 30 years ago. In 2007 a new type of HTS tape became available consisting of YBCO film on a Hastelloy substrate and copper cladding on the outside. This tape has enabled a 32 T all-superconducting user magnet to be built in Tallahassee. While many HTS test coils have been built over the years, they were not intend to be put into routine service for science, they were operated for a few hours to demonstrate feasibility of the technology. The NHMFL's 32 T is has met all performance criteria and is expected to be the first magnet in routine service to provide significantly higher field than the 23.5 T available from Low-Temperature Superconductors.
Various magnet concepts (different fields, bores, and construction techniques) suitable for axion detection will be presented.

Summary:

The emergence of ultra-high field magnets based on High-Temperature Superconductors enables a new era in axion detection.

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Wilkinson Power Combiners for Axion Detection

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We present on the research & development of Wilkinson power combiners at Washington University.

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Workshop Closeout